Space XML Study for the SNDC2 SPO

To Semi-Structured Data and Metadata Subpanel

of the COE Data Access Technical Working Group

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MITRE

Overview

- XML Terminology
- Task Background
- Ontology effort
- Demonstration effort
- Conclusions

XML Terminology

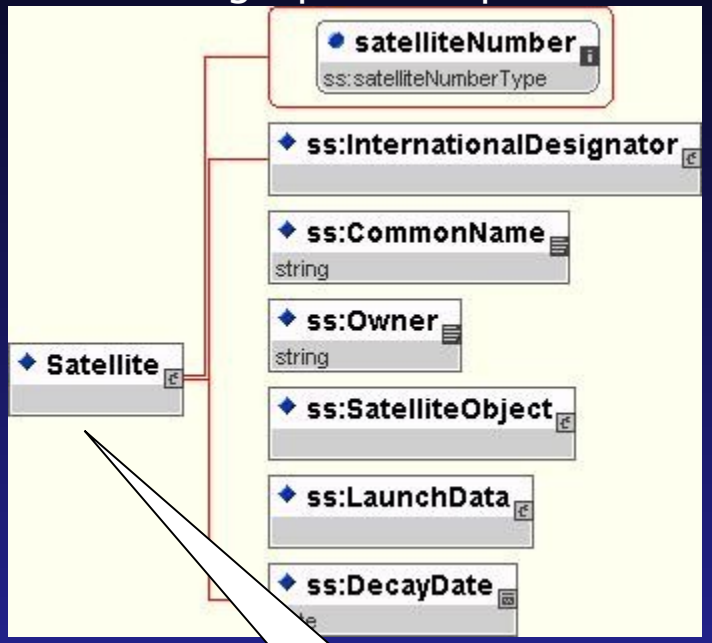
XML Schema (.xsd file)

```
<element name = "Satellite">
  <complexType>
    <annotation>
      <documentation>Manmade space object.
</documentation>
    </annotation>
    <sequence>
      <element ref = "ss:InternationalDesignator"/>
      <element ref = "ss:CommonName
      <element ref = "ss:Owner"/>
      <element ref = "ss:SatelliteObject
      <element ref = "ss:LaunchData"/>
      <element ref = "ss:DecayDate"/>
    </sequence>
    <attribute name="satelliteNumber"
type="ss:satelliteNumberType"/>
  </complexType>
</element>
```

Satellite

Specifies instance document format

XML Schema graphical representation



Satellite

XML Instance (.xml file)

```
<Satellite satelliteNumber="17940">
    <InternationalDesignator classLevel="U">
        <LaunchYear>1987</LaunchYear>
        <LaunchNumber>39</LaunchNumber>
        <PieceIdentifier>A</PieceIdentifier>
    </InternationalDesignator>
    <CommonName classLevel="U" source="TASS">COSMOS
1843</CommonName>
  . . .
</Satellite>
```

Satellite

XML tagged data

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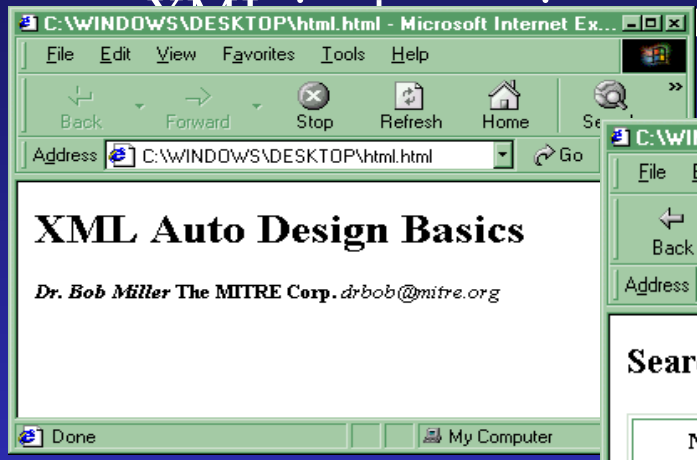
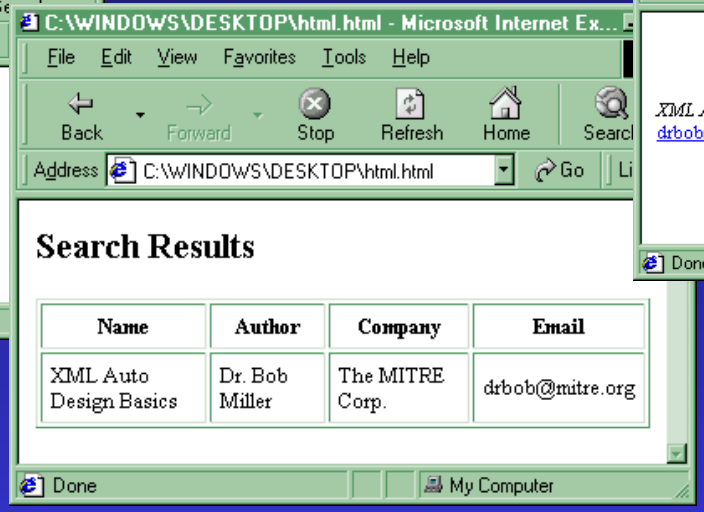
XML Transformations

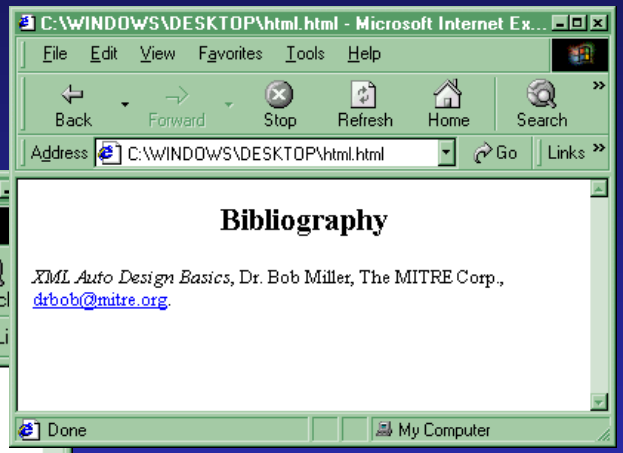
- XML is a markup language
  - International standard for data exchange
- XML is an extensible set of tags to describe the data content
- Extensible Stylesheet Language (XSL) can be used to transform an XML ny ways

XML Example:

```
<Book>
   <Title> XML Auto Design Basics </Tit
   <Author>
      <Name> Dr. Bob Miller </Name>
      <Affil> The MITRE Corp. </Affil>
      <Email> drbob@mitre.org </Email>
   </Author>
</Book>
```







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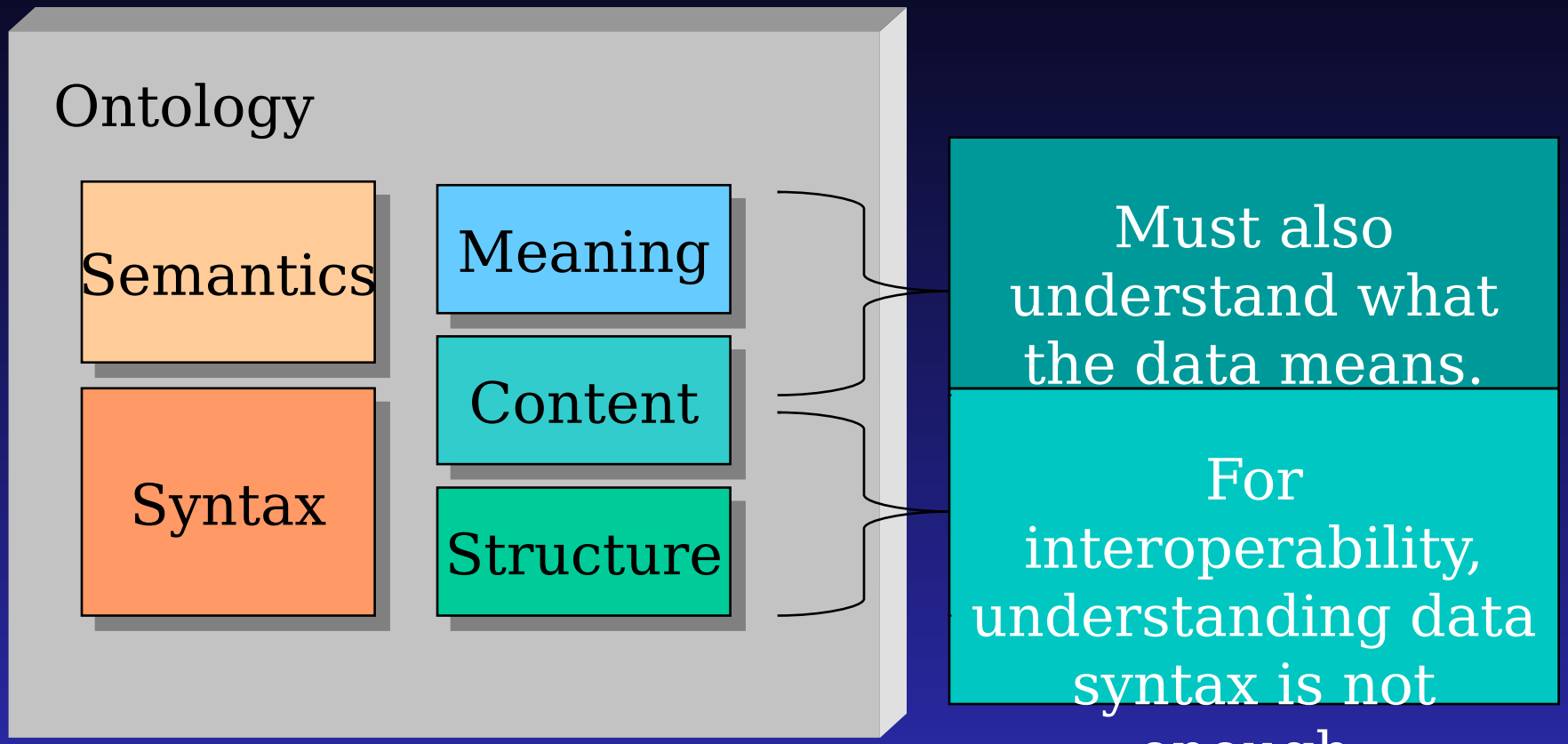
Task Background

- Mr. Steele (SPO Director) attends General Officer “Digitization of Space Workshop” - asks what impact XML may have on new contract
- MITRE’s response
  - Provided more detailed XML overview
  - Proposed and conducted XML study
    - Space ontology task
    - XML demonstration task

Ontology Task

- Ontology details
  - What is an ontology?
  - The ontology development process
  - Space Surveillance - the target domain
  - Our ontology approach using XML Schema
  - Space Surveillance Ontology Contents
- Lessons Learned
- Impacts and Interest

What is an ontology?



Ontology = the definitions of the information elements, the individual data items, and the associated inter-relationships

Ontology Development Process

- Developed preliminary ontology approach
- Researched relevant XML efforts
- Selected space surveillance as target domain
- Selected XML Schema rather than Document Type Definition (DTD) vocabulary
- Participated in XML training
- Developed XML ontology approach using only XML Schemas
- Researched XML tools
- Developed space surveillance schema
- Developed ontology demonstration approach
- Researched registration process for DISA DII COE XML Registry
- Documented Space Surveillance Ontology

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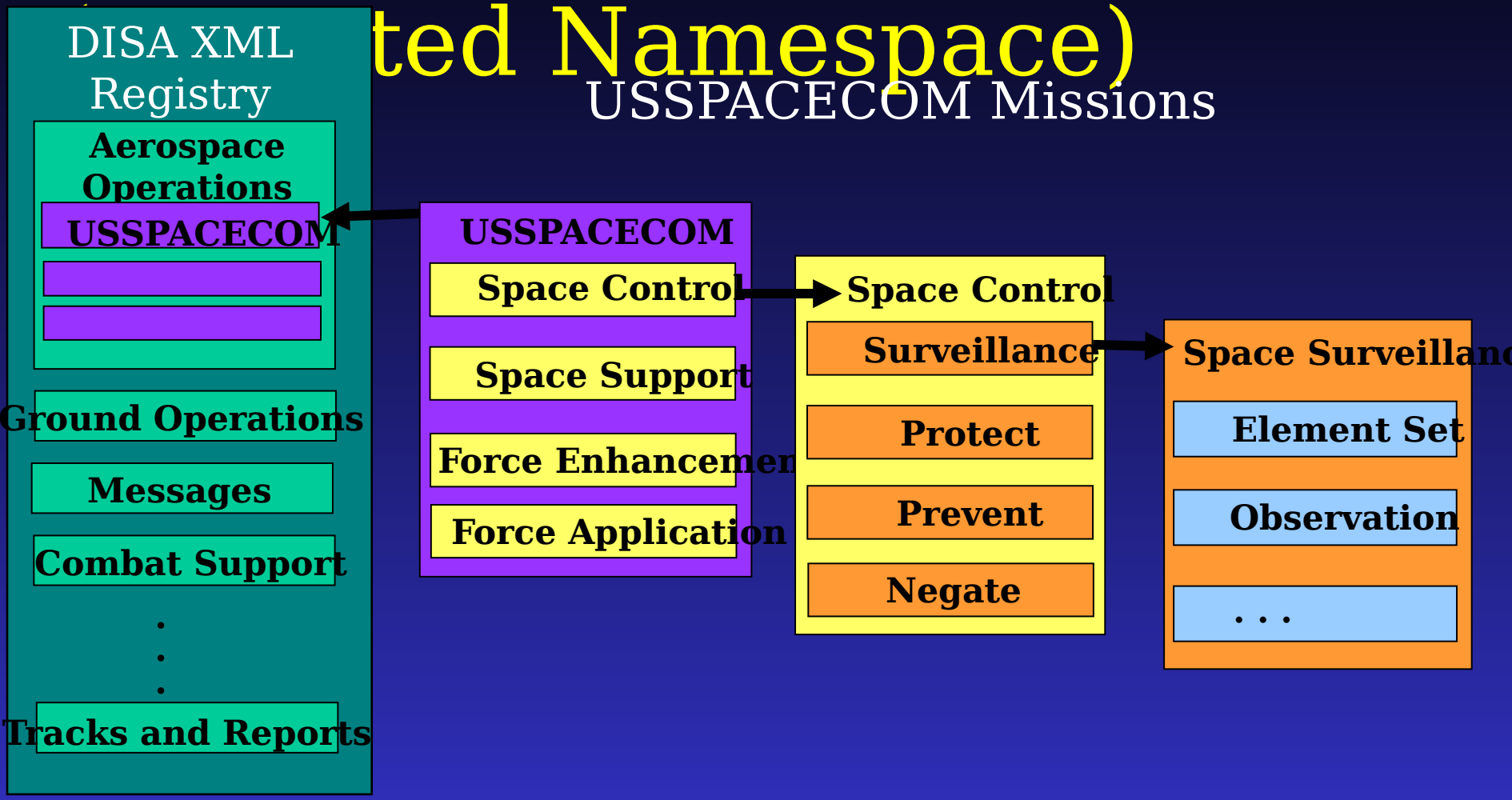
Why Space Surveillance?

- Key mission for United States Space Command (USSPACECOM)
- Prerequisite for all other operations that use space assets
  - A current catalog of where things are in space is a foundation for the military space domain
- Data content and usage well understood
  - Effort not complicated by trying to define how data to be used
- Data content, although vital, does not have stringent delivery time requirements
  - XML tags add overhead
  - Didn’t want value of XML based approach obscured by stringent performance requirements
- Mission targeted by XML demonstration task

Space Surveillance Ontology Context

ted Namespace)



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DTD vs XML Schema

DTD

- Element datatypes limited to aggregates or string data (#PCDATA)
- No type inheritance

XML Schema

- Strong data typing
  - Over 40 built-in types
  - Can define own datatypes
  - Can define patterns (e.g., (ddd) ddd-dddd) using facets
- Supports type inheritance
  - Can extend or restrict a type
    - Simple types with facets
    - Complex types can contain elements & attributes

DTD vs XML Schema

DTD

- Different syntax used
- No Namespace support

XML Schema

- Common file syntax
  - Schemas are XML documents
  - Same tools can operate on data files and schema files
- Supports Namespaces
  - Naming disambiguation
  - Include or Import elements from other namespaces
- Built-in annotation element
  - To document information for humans or other applications

DTD vs XML Schema
Why does it matter?

- Constraint/type checking at data creation is cheaper
  - Software engineering rule of thumb: The earlier you find the error, the cheaper to correct it
    - Strong data typing allows data integrity checking at data creation
  - Estimates of 40% or more of source code is dedicated to data integrity checking
    - With strong data typing, XML validator can do much of this
- Complex information objects can be represented more naturally
  - Through the use of types and inheritance in an object-like approach
- Use of namespaces is powerful
- Commercial vendor XML Schema support is increasing

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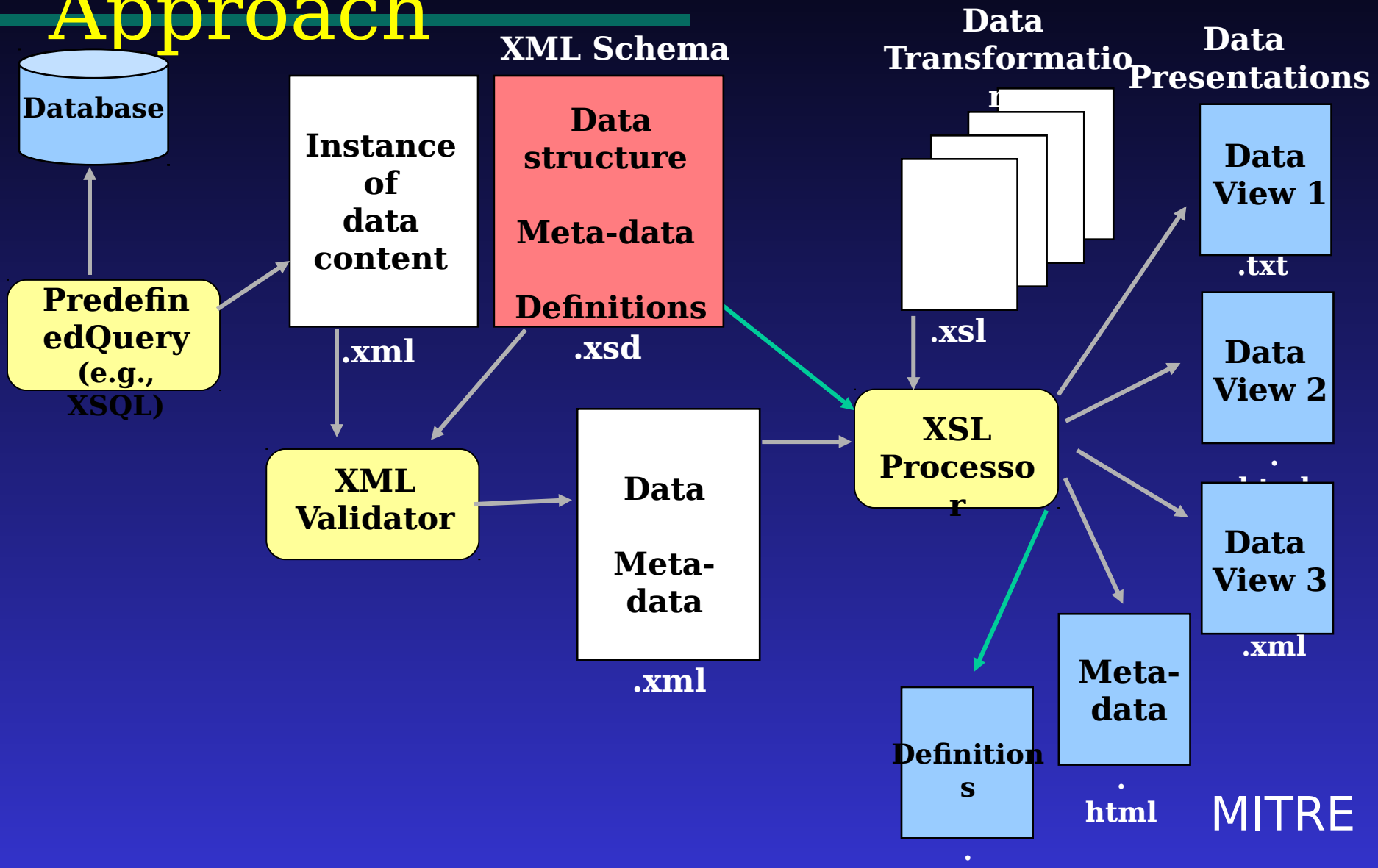
Space Surveillance Ontology

Requirement	XML Schema approach	Example
Capture data structure and content	Inherent part of XML schema (DTDs define structure, schema data types add content information)	<element name = "LaunchNumber" type = "positiveInteger">
Capture relationships between data elements	Inherent part of XML schema	Satellite contains InternationalDesignator, CommonName, Owner, …
Capture data semantics	Use data attributes to capture metadata	CommonName has attribute for source of the name
	Use XML annotation element to capture data definitions	SatelliteNumber = Cataloged satellite numeric identifier assigned by USSPACECOM
Make data, metadata and semantics accessible to a wide variety of clients	XML schema and XML instance files both "well-formed" XML documents Use XSL to transform XML documents to make content readable to humans or other computers	See next chart.
Ensure parallelism between data structure definition and data semantics	Consistency ensured by having both part of same XML schema	See next chart.

Power lies in the simplicity

Specification matches implementation

Space Surveillance Ontology Approach



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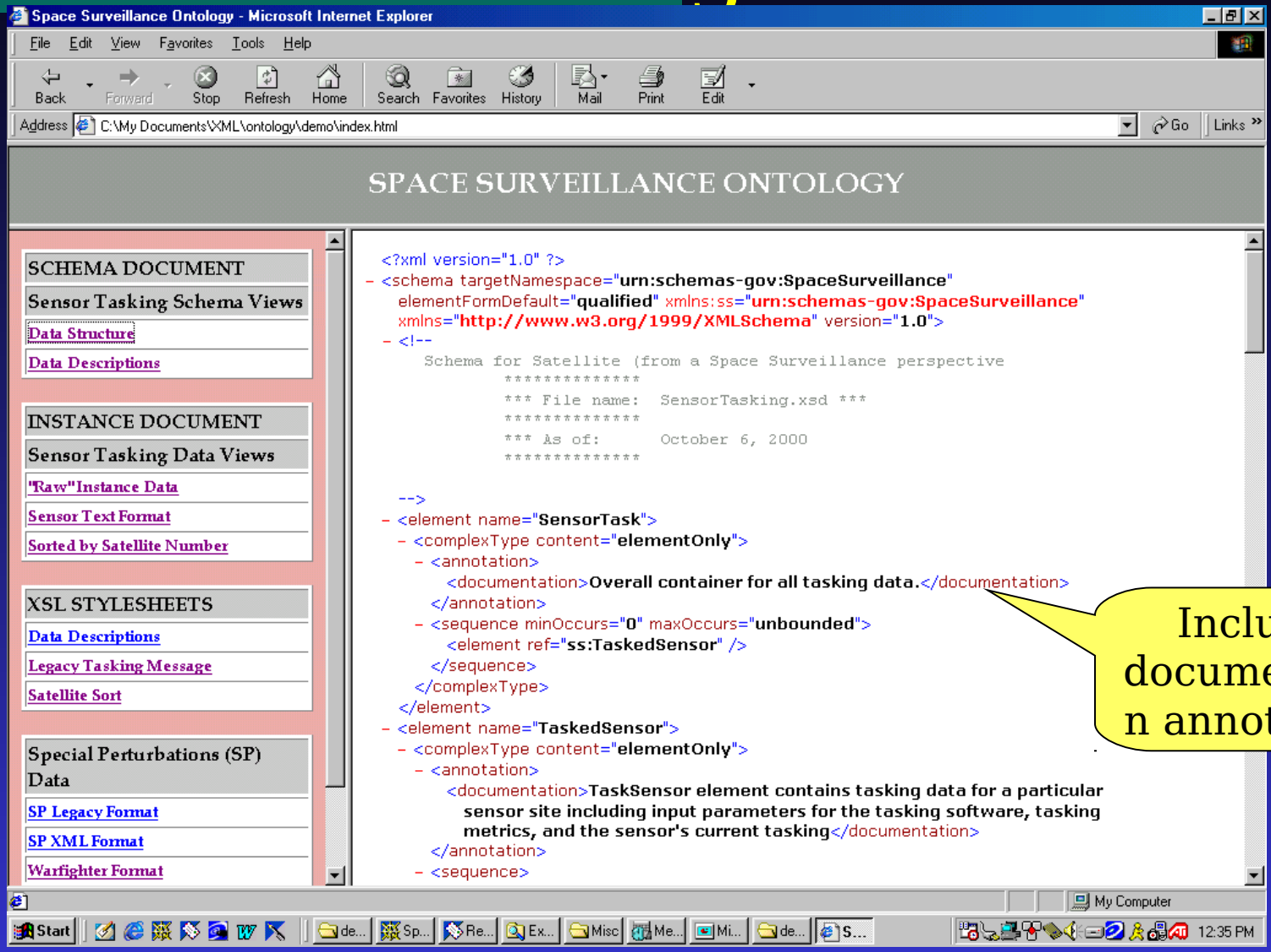
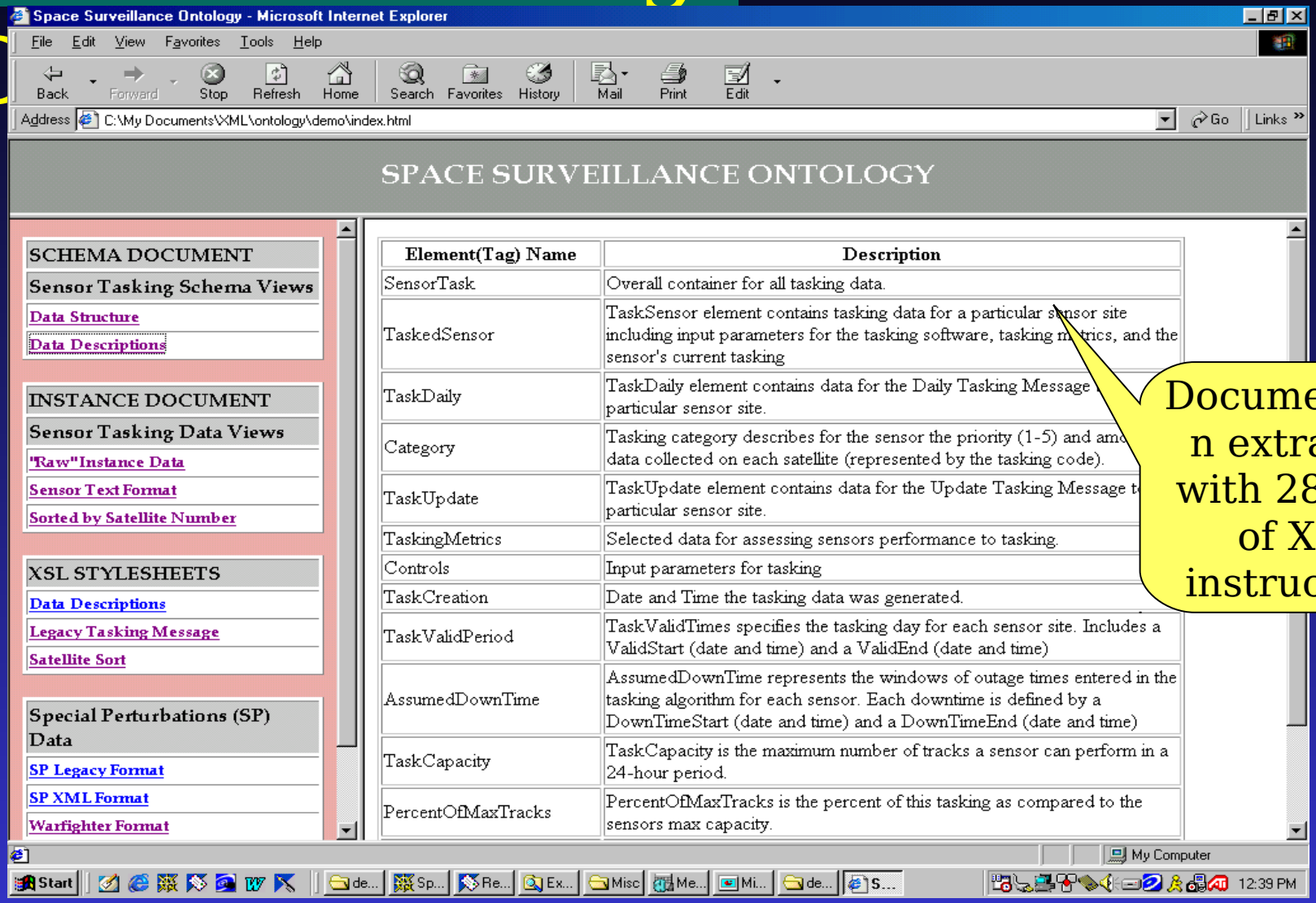
Ontology Demo: Sensor Tasking Schema



Includes documentation annotations

Ontology Demo: Sensor Tasking Element D


Space Surveillance Ontology - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites History Mail Print Edit
Address C:\My Documents\XML\ontology\demo\index.html
Go Links
SPACE SURVEILLANCE ONTOLOGY
SCHEMA DOCUMENT
Sensor Tasking Schema Views
Data Structure
Data Descriptions
INSTANCE DOCUMENT
Sensor Tasking Data Views
"Raw" Instance Data
Sensor Text Format
Sorted by Satellite Number
XSL STYLESHEETS
Data Descriptions
Legacy Tasking Message
Satellite Sort
Special Perturbations (SP) Data
SP Legacy Format
SP XML Format
Warfighter Format
Element(Tag) Name
Description
SensorTask
Overall container for all tasking data.
TaskedSensor
TaskSensor element contains tasking data for a particular sensor site including input parameters for the tasking software, tasking metrics, and the sensor's current tasking
TaskDaily
TaskDaily element contains data for the Daily Tasking Message
particular sensor site.
Category
Tasking category describes for the sensor the priority (1-5) and am
data collected on each satellite (represented by the tasking code).
TaskUpdate
TaskUpdate element contains data for the Update Tasking Message t
particular sensor site.
TaskingMetrics
Selected data for assessing sensors performance to tasking.
Controls
Input parameters for tasking
TaskCreation
Date and Time the tasking data was generated.
TaskValidPeriod
TaskValidTimes specifies the tasking day for each sensor site. Includes a ValidStart (date and time) and a ValidEnd (date and time)
AssumedDownTime
AssumedDownTime represents the windows of outage times entered in the tasking algorithm for each sensor. Each downtime is defined by a DownTimeStart (date and time) and a DownTimeEnd (date and time)
TaskCapacity
TaskCapacity is the maximum number of tracks a sensor can perform in a 24-hour period.
PercentOfMaxTracks
PercentOfMaxTracks is the percent of this tasking as compared to the sensors max capacity.
Documentation extracted with 28 lines of XSL instructions
My Computer
Start
12:39 PM

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Space Surveillance Ontology Contents

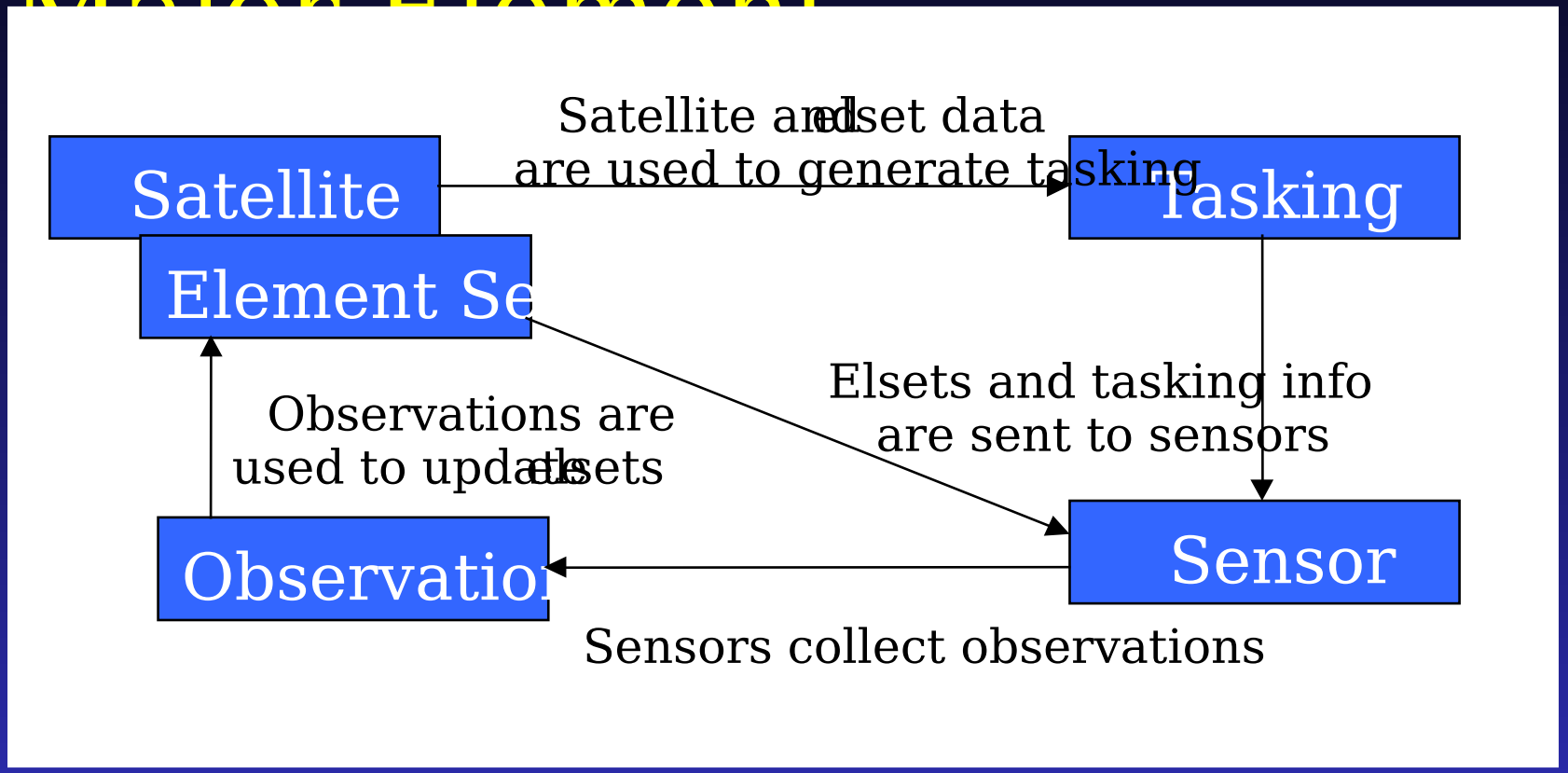
- Architecture
  - *SpaceSurveillanceData* container element holds 5 major elements
  - Each major element in separate file
    - Contains relevant element and attribute declarations
    - Contains relevant type definitions
  - *SpaceSurveillanceGlobals* file holds type definitions and attribute declarations that apply across all major elements
    - To facilitate reuse
    - To isolate items that may change as schema evolves
- Metrics
  - 93 elements
  - 39 user defined types
  - 1 attribute group used 16 times
  - 34 attributes

Initial Schema developed in only 2-3 weeks

Not the hard part

Space Surveillance Schema

Major Element



Lessons Learned During Development

- An XML schema can capture needed data semantics
- The most difficult part of XML schema development is determining the major information objects
- XML is not about terseness
- Our ontology approach is “pushing the technology envelope”
- XML Schemas are superior to DTDs
- Schema development is relatively easy with strong domain knowledge available
- Reuse is powerful and easy to do with XML schemas
- Incremental integration eased development
- It is relatively easy to transform XML tagged data

Ontology Impacts and Interest

- DISA DII COE XML Registry
  - Details on how captured an ontology using XML Schema vocabulary
  - How to accommodate some XML schema features (e.g., type and element inheritance, importing from other namespaces, and attribute groups)
- Aerospace Operations Namespace Manager - Mr. Ray Spinosa, ESC/DIVD
  - How to use sub-domains for naming disambiguation
  - Approach for data standardization
- Dr. Costello - Introduction to XML and its Technologies course
  - Included our approach in his course as a possible strategy for defining the semantics of XML elements
  - Course being given across DoD and at International XML conferences

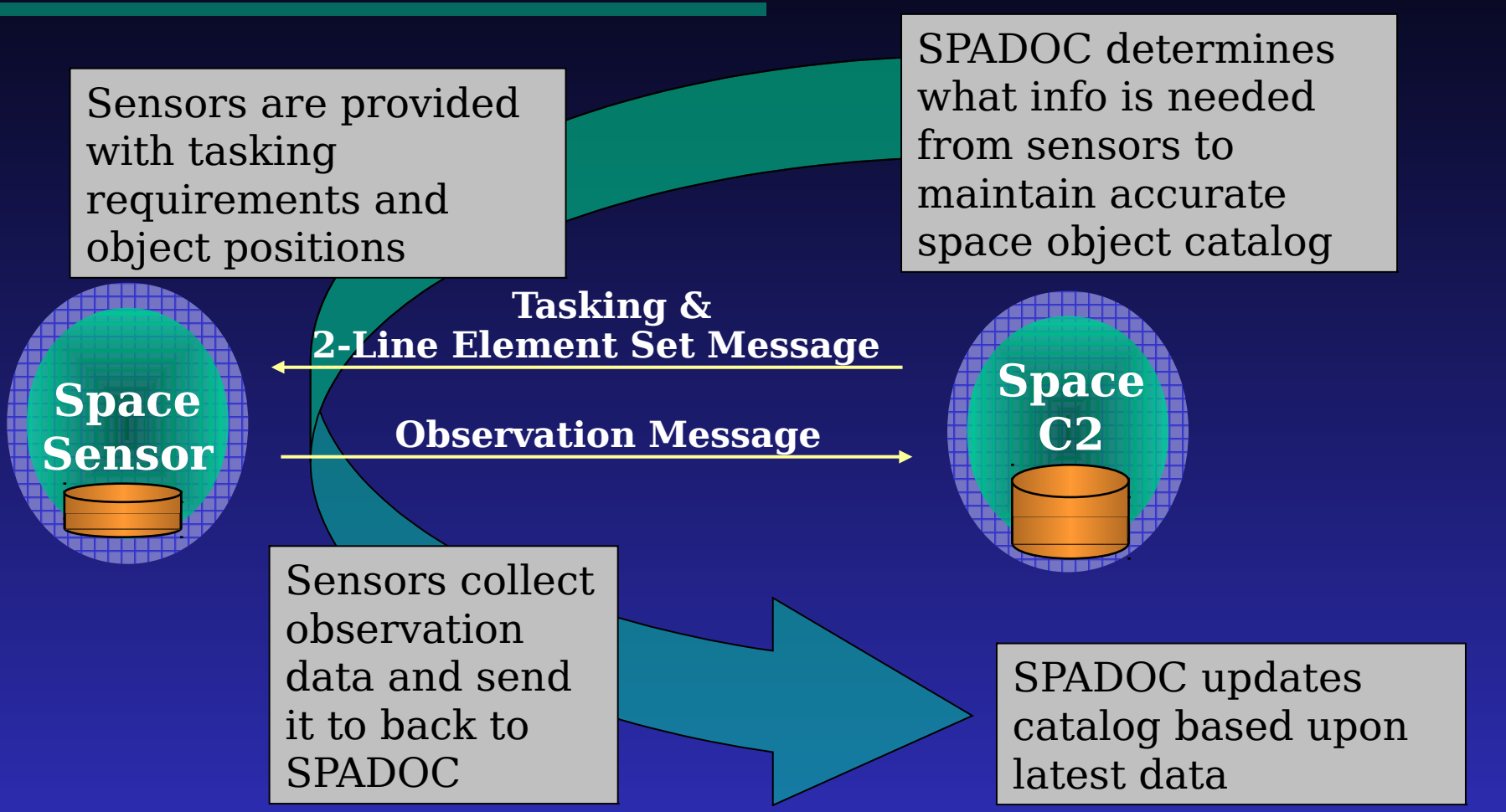
Impacts and Interest (concluded)

- Object Mgmt Group (OMG) Space Domain Task Force (DTF)
  - Recognize XML can play large role in space standards
  - Hosted Dec. '00 Information Day on space technologies & standards
  - Requested we brief our XML schema work
- Joint Battlespace Infosphere (JBI) Architecture Working Group
  - Including our ontology in draft initial guidance for JBI web enablement
  - Draft guidance to SPOs is to define information objects using XML and submit definitions to the DII COE XML Registry
  - Also defining JBI Metadata Standard
    - Standard metadata for each JBI information object
    - Includes standard security tagging approach

Demonstration Task Overview

- Purpose:
  - Investigate new Space Surveillance information delivery methods using XML
  - Implement XML testbed to help clarify user requirements
- Approach:
  - Implement XML testbed for Space
    - Sensor
    - Space C2
    - Space Data User
  - Explore distribution options for higher precision space catalog information

Sensors <--> Space C2


Sensors are provided with tasking requirements and object positions
SPADOC determines what info is needed from sensors to maintain accurate space object catalog
Tasking & 2-Line Element Set Message
Observation Message
Space Sensor
Space C2
Sensors collect observation data and send it to back to SPADOC
SPADOC updates catalog based upon latest data

Migration of legacy sensor systems is biggest challenge

C2 <--> Space Data Users

Space C2 maintains profile for each user including data and format requirements

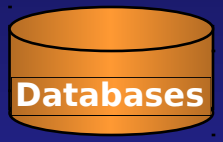
Space data users subscribe to satellite information

Human Interfaces

Space C2

Vector Covariance Matrix (VCM) Message

Application Interfaces



Data Interfaces

Space C2 pushes new data to user and provides ability to pull resident data as needed

Mobile Interfaces

Diversity of Forward Users Highlights XML's Strengths

What is ASW and VCM?

- Astrodynamics Support Workstation (ASW) produces the High Accuracy Catalog of all man-made, earth orbiting space objects
- Vector Covariance Message (VCM) is the message containing information about a satellite's position, velocity, model parameters, & covariance data
  - Covariance data allows the user to predict model errors, in other words predict the uncertainty of the solution over time
- Data is used by NASA and NRO to predict and avoid collisions in space
- Many others interested in higher precision data including Air Based Laser and National Oceanic & Atmospheric Administration (NOAA)

VCM Data Sample Formats

builds custom file formats for each user

```
SP VECTOR/COVARIANCE MESSAGE - V2.0
<>
<> MESSAGE TIME (UTC):                          CENTER:
<> SATELLITE NUMBER: 25544                  INT. DES.: 1998-067A
<> COMMON NAME:
<> EPOCH TIME (UTC): 2000 098 (07 APR) 23:58:29.001  EPOCH REV:
 7898
<> J2K POS (KM):     -5538.57481532    3656.10663450
1071.64870040
<> J2K VEL (KM/S):  -1.866436644539  -4.578115908485
5.912790441600
<> ECI POS (KM):     -5538.78779023    3655.79740204
1071.60291849
<> ECI VEL (KM/S):  -1.866134343695  -4.578109303934
5.912890971292
<> EFG POS (KM):      4300.50210429   -5054.57282873
1071.60291849
<> EFG VEL (KM/S):   2.699496554617   3.563052547800
5.912890971292
<> GEOPOTENTIAL: EGM-96 36Z,36T  DRAG: JAC70/MSIS90
LUNAR/SOLAR:  ON
<> SOLAR RAD PRESS: OFF  SOLID EARTH TIDES: OFF  IN-TRACK
THRUST: OFF
<> BALLISTIC COEF (M2/KG):  0.862748E-02 BDOT (M2/KG-S):
0.000000E+00
<> SOLAR RAD PRESS COEFF (M2/KG):  0.000000E+00  EDR(W/KG):
0.28E-01
<> THRUST ACCEL (M/S2):  0.000000E+00  C.M. OFFSET (M):
0.000000E+00
<> SOLAR FLUX: F10: 178  AVERAGE F10: 185  AVERAGE AP:  13.3

<> TAI-UTC (S): 32  UT1-UTC (S):  0.26879  UT1 RATE (MS/DAY):
-1.105
<> POLAR MOT X,Y (ARCSEC):  0.0775  0.3447 IAU 1980 NUTAT:   4
TERMS
<> TIME CONST LEAP SECOND TIME (UTC): 2049 365 (31 DEC)
23:59:59.999
<> INTEGRATOR MODE: ASW          COORD SYS: J2000  PARTIALS:
FAST NUM
<> STEP MODE: AUTO  FIXED STEP: OFF  STEP SIZE SELECTION:
MANUAL
<> INITIAL STEP SIZE (S):   20.000  ERROR CONTROL: 0.100E-13

<> VECTOR U,V,W SIGMAS (KM):          0.0167     0.0619     0.0115
<> VECTOR UD,VD,WD SIGMAS (KM/S):     0.0001     0.0000     0.0000

<> COVARIANCE MATRIX (EQUINOCTIAL ELS): ( 7x 7) WTD RMS:
0.93559E+00
<>  0.57121E-11 -0.16688E-11  0.20475E-11  0.10855E-10 -0.34769E-
11
<>  0.69095E-10  0.57944E-13 -0.19646E-13  0.11062E-11  0.23833E-
13
<>  0.16990E-12 -0.21940E-14 -0.27400E-12  0.21899E-14  0.81057E-
12
<>  0.30841E-12 -0.14450E-12 -0.26118E-12  0.31887E-14  0.34257E-
12
<>  0.86547E-12  0.21213E-09 -0.15421E-09  0.62902E-08  0.14626E-09
<> -0.21287E-10  0.29761E-10  0.93190E-06
```

Full VCM Message for 1 Satellite

SP equivalent of GP 2-line element set

```
<> EPOCH TIME (UTC): 2000 098 (07 APR) 23:58:29.001  EPOCH REV:  7898
<> J2K POS (KM):     -5538.57481532    3656.10663450    1071.64870040
<> J2K VEL (KM/S):  -1.866436644539  -4.578115908485   5.912790441600
```

Data required for space track (10% of total)

```
EPOCH TIME (UTC): 2000 098 (07 APR) 23:58:29.001  EPOCH REV:  7898
<> J2K POS (KM):     -5538.57481532    3656.10663450    1071.64870040
<> J2K VEL (KM/S):  -1.866436644539  -4.578115908485   5.912790441600
COVARIANCE MATRIX (EQUINOCTIAL ELS): ( 7x 7) WTD RMS:  0.93559E+00
<>  0.57121E-11 -0.16688E-11  0.20475E-11  0.10855E-10 -0.34769E-11
<>  0.69095E-10  0.57944E-13 -0.19646E-13  0.11062E-11  0.23833E-13
<>  0.16990E-12 -0.21940E-14 -0.27400E-12  0.21899E-14  0.81057E-12
<>  0.30841E-12 -0.14450E-12 -0.26118E-12  0.31887E-14  0.34257E-12
<>  0.86547E-12  0.21213E-09 -0.15421E-09  0.62902E-08  0.14626E-09
<> -0.21287E-10  0.29761E-10  0.93190E-06
```

Data required for Air Based Laser (~33% of total)

MITRE

MITRE Demo

- Demonstrates ability to distribute Vector Covariance Matrix (VCM) data using XML and web-based approach
  - VCM data is received via CD ROM, parsed and XML tagged
  - Allows for storage of data in a database, Oracle in our demo
- XML Stylesheet Language (XSL) used to easily format data in several ways
  - Text, HTML, XML, WAP
  - Full VCM message, Warfighter (ABL), SPADOC State Vector, WAP Notification
- Allows for automatic distribution of data via several methods
  - E-mail (Push)
  - Socket Subscription (Push to a client directory)
  - Web Access - Limited access to assigned directory with only requested and approved VCMs (Pull on demand)
- Distribution method and format controlled by entries in a database, Access in our demo

Demo Results/Impact

- Demonstrated ability of XML to address distribution issues
- Presented demonstration to Space Surveillance community
- Working with user community and contractor to provide increased access to prototype in order to clarify user's requirements

Space XML Task Briefings

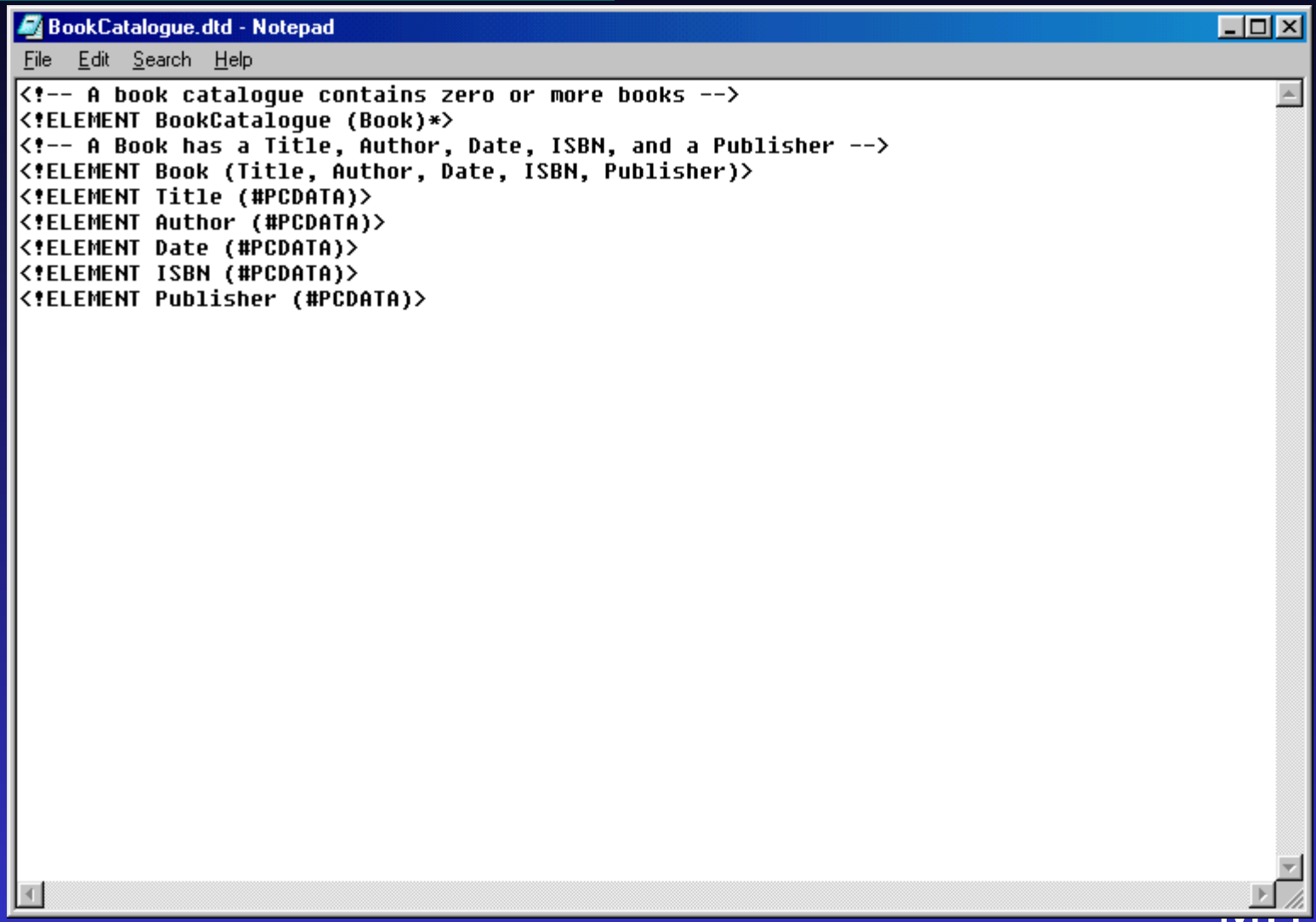
- ESC/ND: Task sponsors (Nov-Dec ‘00)
  - And their contractors
- MITRE Management (Nov-Dec ‘00)
- USSPACECOM/J2Y, J2F: XML technology interest (Dec ‘00)
- Object Management Group (OMG) Space Domain Task Force: XML space standards role (Dec ‘00)
- 1st Command & Control Squadron: Way to distribute VCM data (Dec-Jan ‘00)
- Air Based Laser Program Office: Means to receive VCM data (Jan ‘00)

Conclusions

- XML is a technology of choice for interoperability
  - Internet standard for data structure and data exchange
  - Enjoys tremendous commercial support (e.g., Sun, Microsoft, Oracle, IBM, …) & rapidly maturing
  - Provides data transparency allowing multiple migration strategies
  - Does not solve Information Management problem (e.g., data semantics definition, data storage, operational use)
    - XML is only part of the total solution
- Capturing domain semantics is vital to interoperability
  - XML Schema approach simple & applicable across domains

Backup Charts

DTD Example


BookCatalogue.dtd - Notepad
File Edit Search Help
<!-- A book catalogue contains zero or more books -->
<!ELEMENT BookCatalogue (Book)*>
<!-- A Book has a Title, Author, Date, ISBN, and a Publisher -->
<!ELEMENT Book (Title, Author, Date, ISBN, Publisher)>
<!ELEMENT Title (#PCDATA)>
<!ELEMENT Author (#PCDATA)>
<!ELEMENT Date (#PCDATA)>
<!ELEMENT ISBN (#PCDATA)>
<!ELEMENT Publisher (#PCDATA)>

XML Schema Example

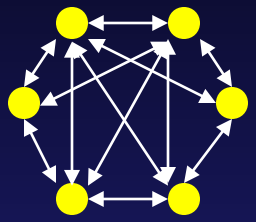
Sensor.xsd - Notepad

File Edit Search Help

```
<?xml version ="1.0"?>
<!--Generated by XML Authority. Conforms to w3c http://www.w3.org/1999/XMLSchema-->
<schema targetNamespace = "urn:schemas-gov:SpaceSurveillance"
         xmlns = "http://www.w3.org/1999/XMLSchema"
         xmlns:ss = "urn:schemas-gov:SpaceSurveillance">


        <!-- Ground-based Sensor from a Space Surveillance Perspective
        ***************
        *** File name:  Sensor.xsd ***
        ***************
        -->

        <element name = "Sensor">
                <complexType content = "elementOnly">
                        <annotation>
                                <documentation>Ground-based sensor used to collect observati
                        </annotation>
                        <sequence>
                                <element name = "ss:SensorNumber"/>
                                <element name = "ss:StationNumber" minOccurs = "1" maxOccurs
                                <element name = "ss:Location"/>
                        </sequence>
                </complexType>
        </element>

        <element name = "SensorNumber" type = "ss:sensorNumberType">
                <annotation>
                        <documentation>Unique identifier for a ground-based sensor.</documen
                </annotation>
        </element>
```

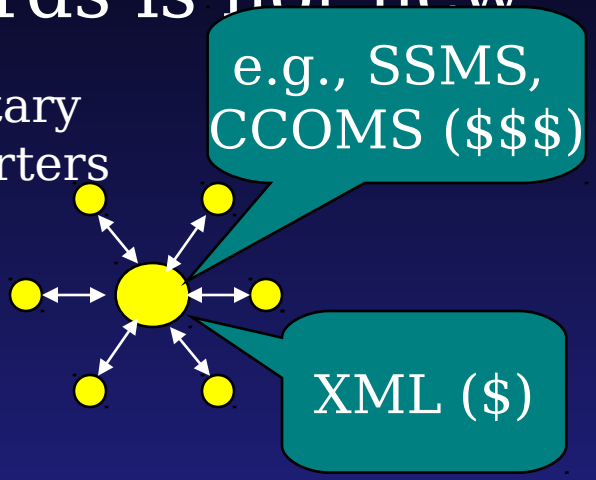
XML is a standard for data exchange

- Use of data exchange standards is not new



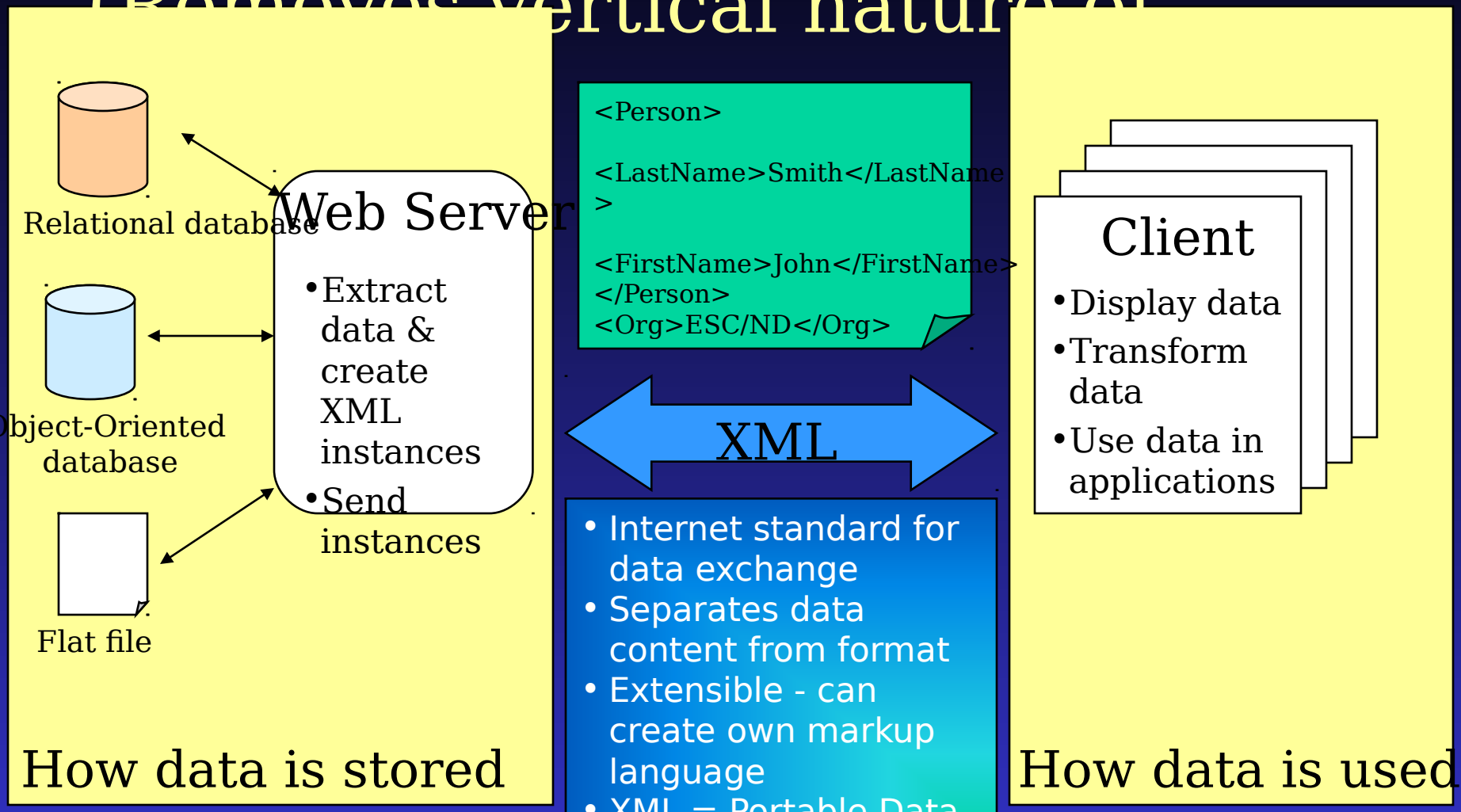
6 programs, each with a proprietary format means 36 different converters

6 programs reading and writing the same format means only 6 converters



- However with XML:
  - Government does NOT need to develop and maintain the standard
  - Government can capitalize on tremendous commercial support for this open standard for web-based data exchange
    - Many inexpensive and free tools available to:
      - View data
      - Develop data instances (.xml files)
      - Define data content (.xsd files)
      - Translate data (APIs, .xsl files)

XML Provides Data Transparency (Removes vertical nature of



Sensor Tasking & Elsets (Pushing Information)

1. Sensor Tasking is Placed in In Box

2. Tasking Message is Parsed into an XML

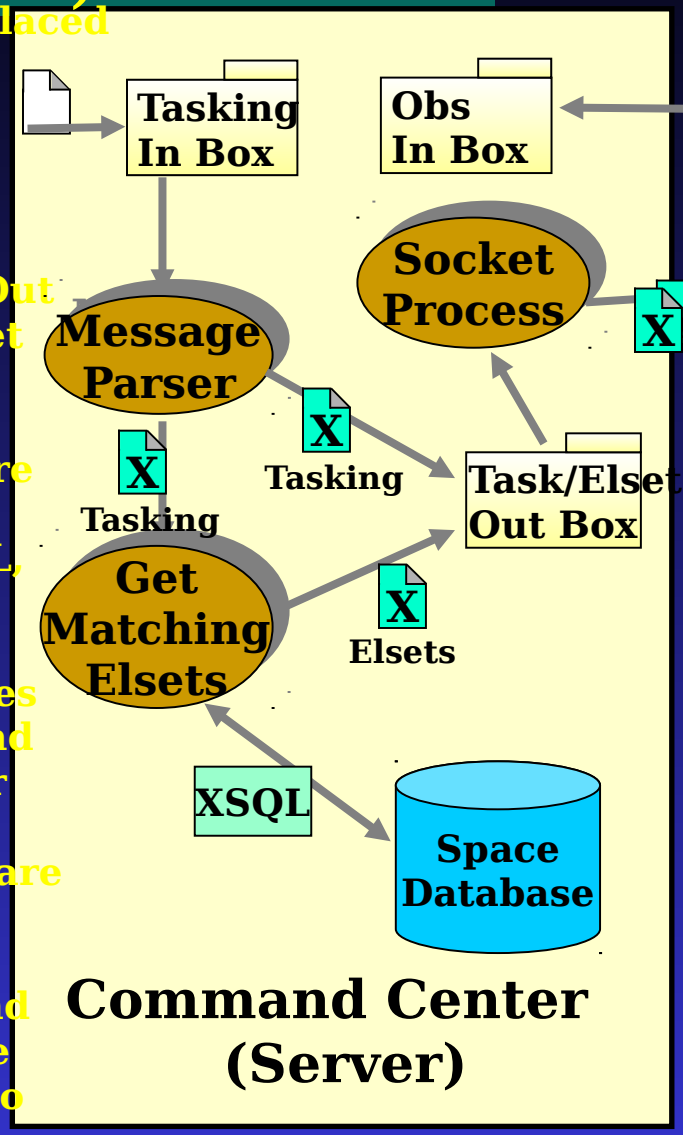
3. Tasking is Sent to Out Box and Process to Get Matching Elsets

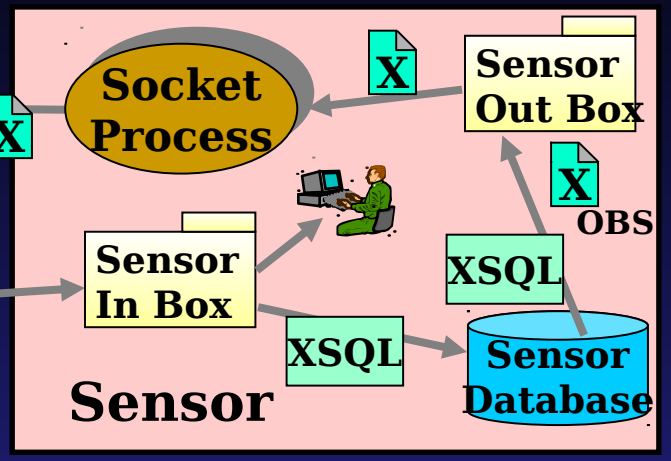
4. Associated Elsets are Extracted From DB, Transformed into XML, and Sent to Out Box

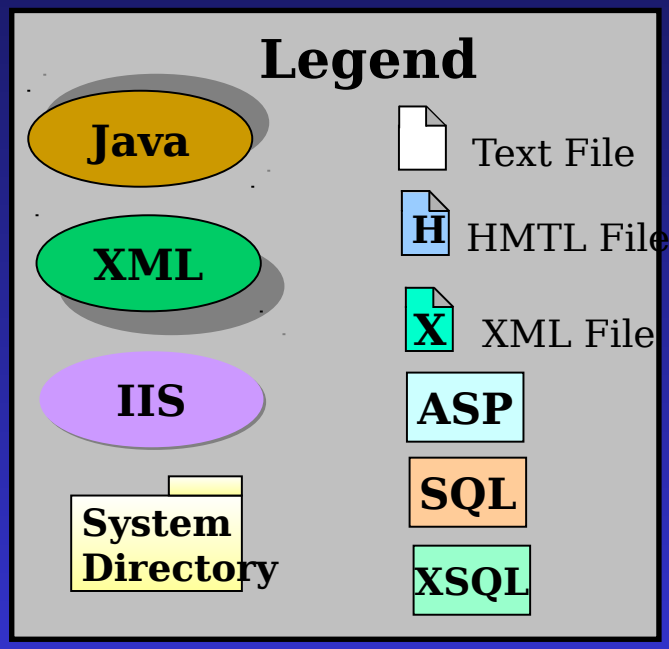
5. Socket Process Takes Tasking and Elsets, and Sends Them to Sensor

6. Tasking and Elsets are Inserted into DB

7. OBS are Created and Sent to Out Box where Process Sends Them to Command Center







VCM Messages (Pushing Information)

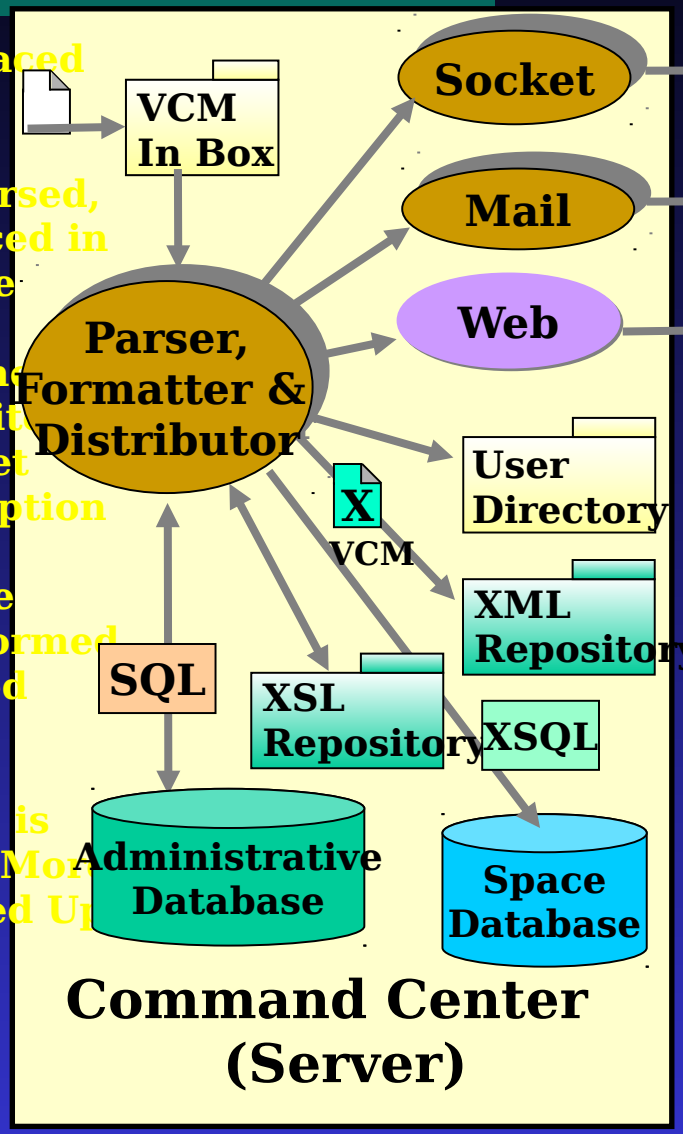
1. VCM Message is Placed in the In Box

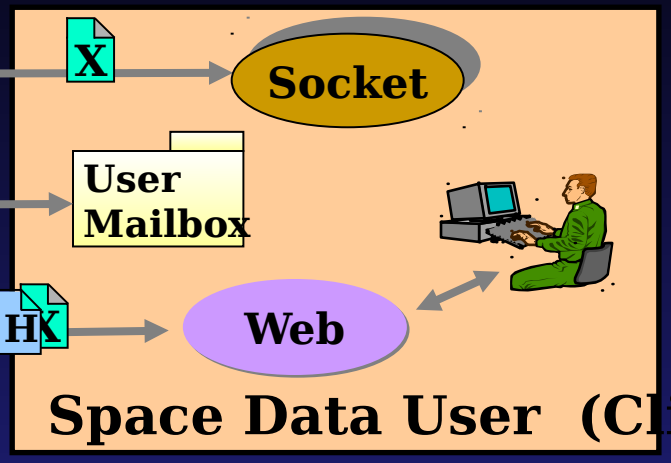
2. VCM Message is Parsed, XML Tagged, and Placed in Repository & Database

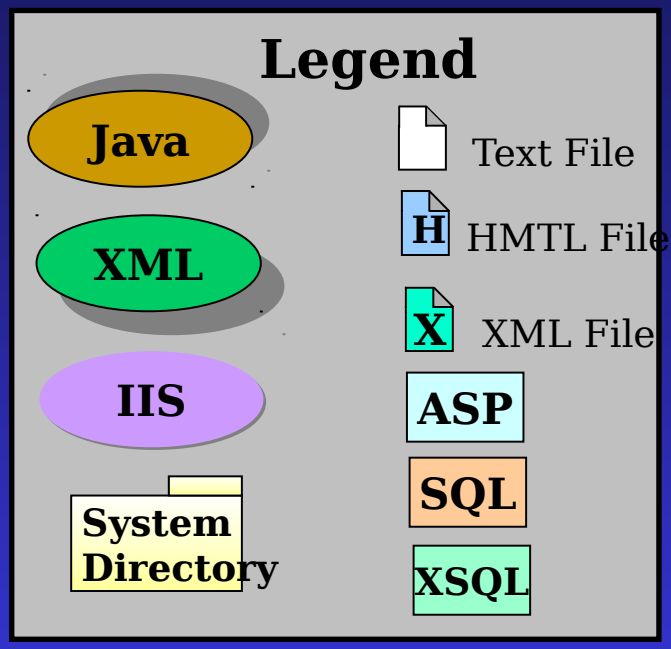
3. User Profiles are Ch to Determine if Satellit Number and Stylesheet Matches User Subscription

4. For Each Match, the Information is Transformed to Match User Selected Format

5. Formatted Message is Distributed to One or Mo Delivery Systems Based U User Profile







Astrodynamics Support Workstation (ASW) Vector/Covariance Matrix (VCM) Distribution

Current Approach

- Separate manual process by ASW analyst for each user
- Two current users: NRO, NASA
  - Two separate scripts to create data
- Adding new user requires analyst to custom build another file
- New users unserviced due to labor intensive effort needed

XML Based Approach

- Manual process occurs once
  - Subsequent replication process automated
  - XSL used to extract desired data and put in desired format
  - Implement with inexpensive commercial tools
  - New users mean a new XSL stylesheet
- Can couple with JBI publish/ subscribe methods to service users
- Unclassified data could be posted on 1stCACS web site, allowing users to pull selected data